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The Worm Creek Quartzite Member of the St. Charles Formation, Utah-Idaho

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THE WORM CREEK QUARTZITE MEMBER OF THE ST. CHARLES FORMATION, UTAH-IDAHO

by

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INTRODUCTION

Statement of the problem

This report presents the results of a stratigraphic study of the Worm Creek quartzite, the basal member of the St. Charles formation of Upper Cambrian age. The member is present in the Bear River Range, the Malad Range, and the Promontory Range of Northern Utah and southeastern Idaho. The Worm Creek quartzite was differentiated as the basal unit of the St. Charles formation by Richardson (1913) and named for its occurrence in Worm Creek Canyon in the Bear River Range, Bear Lake County, Idaho.

A stratigraphic investigation of the Worm Creek quartzite, including thickness and lithologic changes, was made. Through this investigation a source area and environment of deposition was determined. In this connection, it is interesting to note that Hanson (1953) suggested that the sand may have come from central Idaho, which he thought was an island area during Upper Cambrian time; whereas Lochman (1955) postulated that the source area was to the east in the Uintah Mountains area of Utah, which she thought to be a highland during Upper Cambrian time. Both thought that the Worm Creek quartzite represents the basal sand of a transgressive sea.

The area considered in this investigation is located in the vicinity of the Utah-Idaho-Wyoming borders, and extends from Preston, Idaho, on the north to Ogden, Utah, on the south; and from Malad City, Idaho, on the west to Laketown, Utah, on the east (Figure 1). This area lies on the boundary of the Basin and Range and Middle Rocky Mountains province, and includes rt of the Bear River Range of the Middle Rocky Mountains province, and

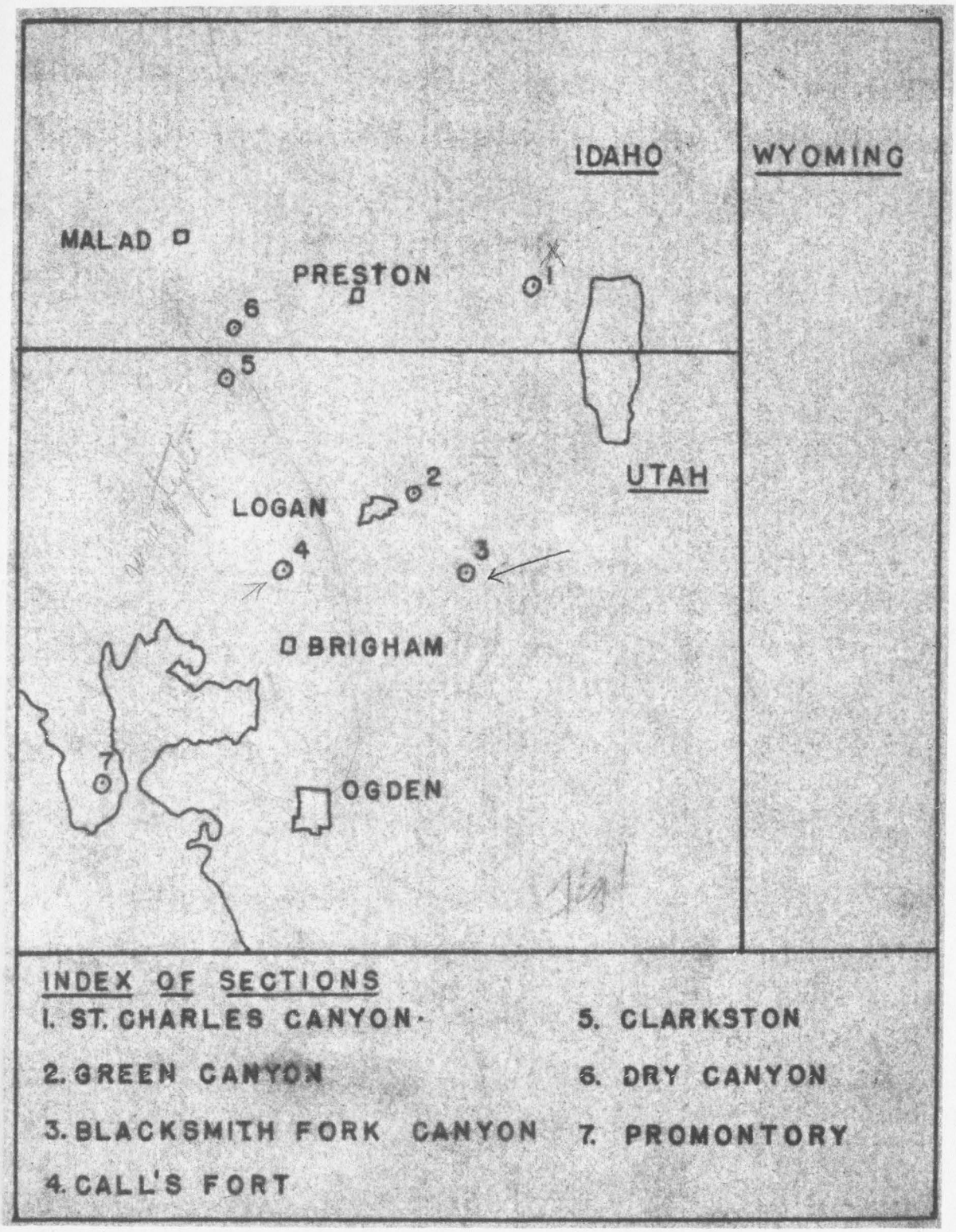


FIGURE 1. Index Map showing area of the Worm Creek Quartzite

parts of the Promontory Range, the Malad Range, and Wellsville Mountain, which are all in the Basin and Range province.

In this area the Basin and Range-Middle Rocky Mountains provinces boundary is almost coincident with the Wasatch Line, which represents the flexure which defined the Cordilleran geosyncline of Paleozoic time, according to Kay (1951). This flexure approximates the transition line from the basin to the shelf area of the Cordilleran geosyncline (Figure 2).

Previous work

Measurements and descriptions of the Worm Creek quartzite have been included in reports on various areas within the area studied. Richardson (1941) measured a thickness of 300 feet for the Worm Creek in the Randolph quadrangle; Mansfield (1927) measured 250 feet of the quartzite near Liberty, Idaho, and 200 feet in Fish Haven Canyon, Idaho; the Liberty section is the most northern known section of the Worm Creek. Thick sections which are supposed to be Worm Creek quartzite have been reported near Soda Springs, Idaho; however, no measurements or other data have been published concerning these. Hanson (1949) mapped the quartzite in the southern Malad Range, near Clarkston, Utah. This was the western-most known extent of the quartzite; however, Richard Olsen (Personal communication) found a section of the Worm Creek in the Promontory Range, west of Brigham City, Utah, during the summer of 1956. Maxey (1941) measured 75 feet of the Worm Creek in the Bear River Range at High Creek; Coulter (1954) measured 170 feet of the quartzite at Willow Flat, near Preston, Idaho; Ezell (1953) measured 15 feet of the Worm Creek in the Rendezvous Peak area, Utah, 17 miles south of Logan, Utah.

FIELD STUDY

The major part of the field work was completed in the spring and

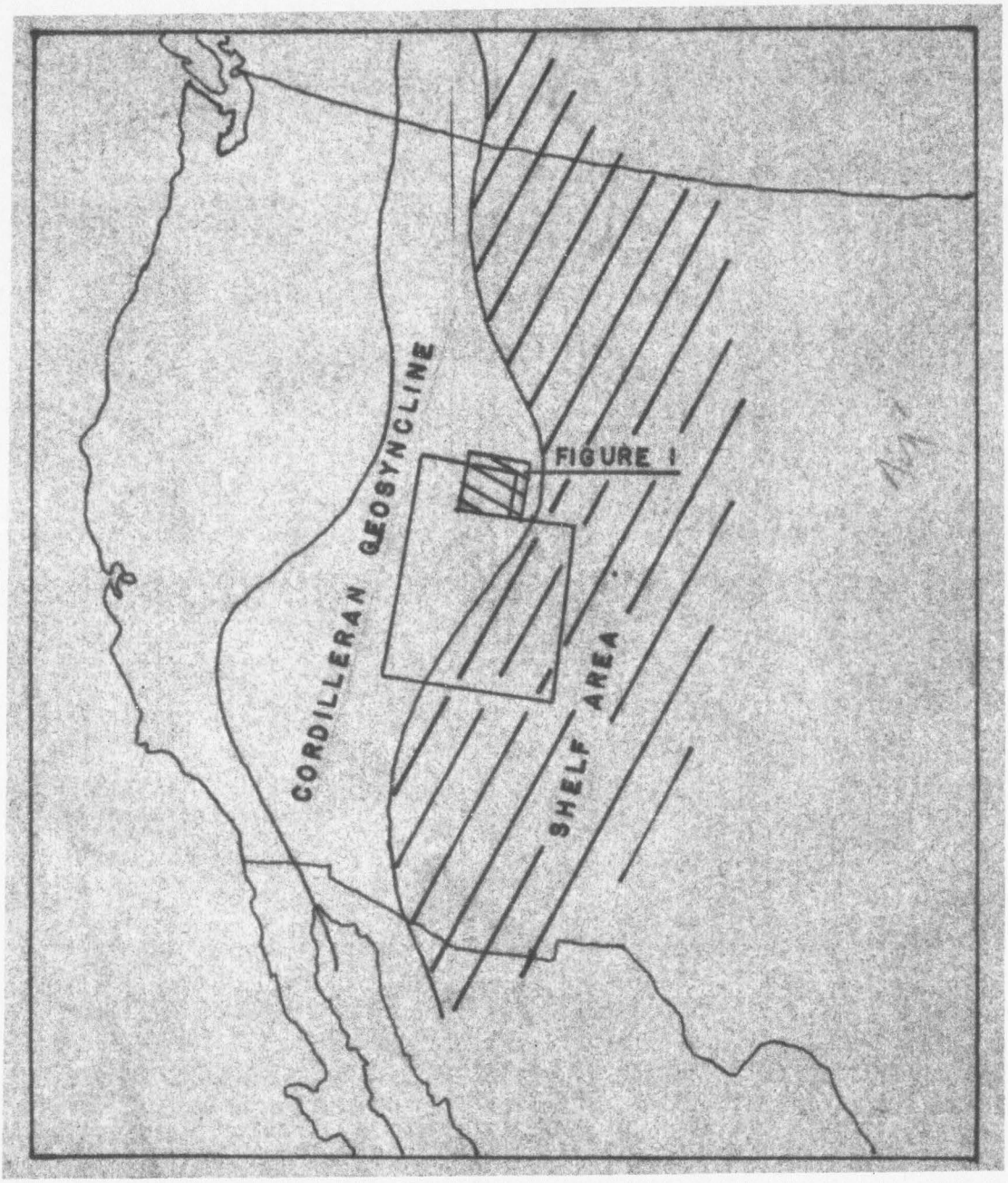


FIGURE 2. Index map showing location of area studied in relation to western states and Cordilleran geosyncline.

early summer of 1956. This field work consisted in the main of remeasuring a number of widely separated sections of the Worm Creek, with accompanying lithologic and fossil sampling. It was felt that a single worker remeasuring the various key sections could maintain a consistancy which could not be obtained by a number of different workers whose time of work and ultimate goals were highly diversified.

U. S. Forest Service maps of the Caribou and Cache national forests were used as a base for orientation and plotting. All measurements were made with a Brunton compass and chain, except in such cases as exposures made direct measurements possible.

Type section

The lithology of the Worm Creek varies considerably from the eastern exposures to those in the west, notably Promontory and Call's Fort; however, the St. Charles Canyon section probably represents the nearest to a type locality of the Worm Creek quartzite, since it is near the original type section and is in an area giving fair exposures. The Worm Creek Canyon section proved entirely inadequate for measurement and comparison.

The Worm Creek generally consists of a basal white quartzite unit which is usually quite blocky. The quartzite is composed of well sorted, sub-angular to rounded quartz grains which are well cemented. Some secondary enlargement can be observed. This basal quartzite unit generally occupies about 1/3 of the total Worm Creek thickness. Overlying this basal quartzite is a calcareous sandstone unit, varying in thickness from about 1/10 to 1/2 of the total thickness. In some cases this central horizon is present as a limestone unit. Above the calcareous unit is usually a slightly calcareous quartzite, with some sandstone layers present. This unit resembles the basal quartzite in physical appearance

and thickness. The upper unit in the eastern exposures is a silty limestone unit, and occupies from 1/3 to 9/10 of the total Worm Creek quartzite. In some areas a green shale unit caps the Worm Creek.

Worm Creek section

The Worm Creek Canyon section is the type section of the Worm Creek quartzite and is located approximately 5 miles up Worm Creek Canyon, 3 1/2 miles north of Paris, Idaho. The section is not easily accessible, although a primitive road from U. S. highway 89 to the area does exist.

The Worm Creek in this area is in the over-thrust sheet of the Bannock over-thrust, but is apparently not badly deformed. The unit is poorly exposed, and a measureable section could not be found; however, it is estimated that the thickness could not possibly reach Richardson's 300 feet, and was probably less than 200 feet. (This estimate is made by comparison with near-by sections.) Much of the hillside on the north side of the canyon was covered by quartzite and sandstone float, but only one bed rock exposure was found. If the quartzite were thought to have been everywhere present under the float, a 300 foot thickness would be present; however, much of this thickness is middle St. Charles and underlying Nounan.

St. Charles Canyon section

The St. Charles Canyon section is located in St. Charles Canyon, Idaho, west of the town of St. Charles, Idaho. The section was measured on the north side of the canyon approximately 5 miles west of St. Charles. The road to the area is graded dirt and in good repair, making the section easily accessible. Measurements were made about 2/3 of the way up the hillside, but the outcrop is fairly well exposed near the road.

Like the Worm Creek Canyon section, this section is in the overthrust

sheet of the Bannock overthrust. The lower part of the canyon is in Triassic rocks, which are overridden by the Cambrian sequence. The rocks in the area measured strike east-southeast and dip 15° west-southwest. The unit in this area is exposed as a series of minor cliffs interrupted by smooth, shallow slopes. The upper silty limestone unit of the Worm Creek forms slopes which tend to obscure the upper contact; however, adequate exposures were found to make a detailed measurement of most of the unit. The upper contact could not be accurately located. The quartzite in this area is overlain by the crinkly limestone middle member of the St. Charles formation, and overlies about 100 feet of silty limestone which overlies the prominent white Nounan cliffs. The Worm Creek quartzite is about 150 feet thick and consists of silty limestone grading down into calcareous sandstone, white quartzite, another calcareous sandstone, and finally another white quartzite. This lower quartzite is well marked with worm burrows at specific horizons (Plate 4). These U-shaped burrows were identified as those produced by the Polychaeta class of marine worms, which is indicative of a beach or littoral environment.

TABLE 1. ST. CHARLES CANYON SECTION

Location - Sec. 19, T 15 S, R 43 E, Bear Lake County, Idaho

Description - Section of Upper Cambrian strata measured on the north side of St. Charles canyon approximately 5 miles from the town of St. Charles, Idaho. The section was measured about 2/3 the way up the hill, and from the crest of the minor eastern spur. The section was measured and sampled by A. V. Haynie Jr. and Darrell Eliason on 23 June 1956. In soluble residue analysis completed July 1956.

Middle member, St. Charles formation conformably overlies the Worm Creek quartzite.

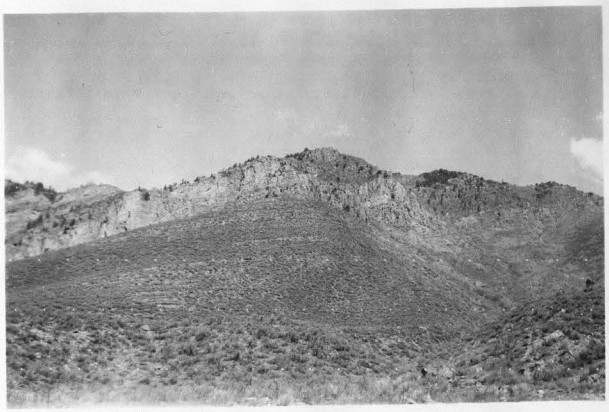
Worm Creek quartzite:		feet	% Clastic
Unit 1.	Limestone, gray sandy; contains minor sand and silt laminae, poorly exposed	75 (approx)	16
Unit 2.	Sandstone, tan, fine-grained, flaggy, dolomitic.	9.0	77
Unit 3.	Quartzite, white, fine-grained, well-cemented, blocky.	24.0	95
Unit 4.	Quartzite, white, fine-grained, medium sorting, flaggy; with minor sandstone.	16.0	91
Unit 5.	Sandstone, white to tan, calcareous; medium sorting.	12.0	84
Unit 6.	Quartzite, white, fine-grained, well-cemented, blocky; with scolite traced on weathered surfaces.	17.0	93
Total thickness Worm Creek quartzite		150.0 (approx)	

The Worm Creek quartzite conformably overlies the Nounan formation.

Blacksmith Fork Canyon section

The Blacksmith Fork Canyon section is located 7 miles up Blacksmith Fork Canyon. The section was measured on the spur north of the Blacksmith Fork Canyon dam, about 2/3 up the spur and below the massive dolomite cliffs (Plate 1). The area studied is easily accessible by automobile as the road is graded and kept in good condition. This section is about 8 miles southeast of Logan and 13 miles from Logan by road distance.

This section is on the southern flank of the Logan Peak syncline of the Bear River Range. The beds strike northeast and dip 24° northwest. The Worm Creek in this area is extremely calcareous, consisting of 71 feet of silty limestone and dolomite and a basal quartzite only 3 feet thick. This basal quartzite is exposed as an obscure, undercut ledge overlain by a thin dolomitic sandstone (Plate 1). As is characteristic of the unit, there is a smooth, covered slope as the upper unit of the Worm Creek quartzite. The minor basal quartzite is



A. Worm Creek quartzite exposed below massive cliffs.

B. Basal Worm Creek quartzite exposure in Blacksmith Fork Canyon

PLATE 1. Worm Creek quartzite in Blacksmith Fork Canyon.

apparently the lower quartzite unit of the Worm Creek.

TABLE 2. BLACKSMITH FORK SECTION

Location - Sec. 6, T 10 N, R 3 E, Cache County, Utah

Description - Section of Upper Cambrian strata measured on the north side of Blacksmith Fork Canyon, approximately 7 miles up the right fork of the Blacksmith Fork Canyon and measured on the spur north of the Blacksmith Fork 2nd dam, about 2/3 the way up to the massive dolomite cliff. Section was measured and sampled by A. V. Haynie, Jr. and J. Stewart Williams on 11 April 1956. Insoluble residue analysis completed July 1956.

Middle member, St. Charles formation conformable overlies the Worm Creek quartzite.

Worm Creek quartzite:		feet	% Clastic
Unit 1.	Limestone, gray, coarsly crystalline, silty, well-bedded	21.7	13
Unit 2.	Dolomite, tan to gray, sandy; contains minor sand and silt laminae, poorly exposed.	49.0	19
Unit 3.	Sandstone, white dolomitic, poorly sorted.	1.9	73
Unit 4.	Quartzite, light gray, fine-grained, well-cemented; weathers to improminent ledge.	1.8	95
Total thickness Worm Creek quartzite		74.4	

The Worm Creek quartzite conformably overlies the Nounan formation.

Call's Fort section

The Call's Fort section is located on the west side of the Wellsville mountains in the canyon south east of Call's Fort, Utah, 5 miles north of Brigham City, Utah. The section was measured on both sides of the canyon, with the quartzite being best exposed on the north side. The area measured is about 1/2 mile up the canyon from the end of the Honeyville water works road. This road is seldom used and is in poor repair.

Steep grades and sharp switch backs make it impassable to automobile traffic; however, a jeep or four-speed pickup can usually negotiate the climb.

The beds in this area strike southeast and dip 44° northeast. The Wellsville mountains are basin and range mountains about 20 miles west of the Basin and Range-Middle Rocky Mountain provinces border. Consequently, this area was just west of the shelf area and into the deep of the Cordilleran geosyncline.

The Worm Creek in this area is about 60 feet thick, with a dolomite and limestone horizon separating the quartzite into two units near the top of the member. This section includes a green shale unit immediately below the crinkly limestone. This shale is typically fissle and is not fossiliferous; the green shale grades into the above limestone.

TABLE 3. CALL'S FORT SECTION

Location - Sec. 25, T 14 N, R 3 W, Box Elder County, Utah

Description - Section of Upper Cambrian strata measured on the north side of canyon southeast of Call's Fort, Utah. Part of section measured on the south side of canyon. Measurement was made approximately 1/2 mile up canyon from end of Honeyville water works road. The section was measured and sampled by A. V. Haynie Jr. and J. Stewart Williams on 22 April 1956. Insoluble residue analysis completed July 1956.

Middle member, St. Charles formation conformably overlies Worm Creek quartzite.

Worm Creek quartzite:		feet	% Clastic
Unit 1.	Shale, green, fissle.	2.0	99
Unit 2.	Sandstone, tan to gray, dolomitic; contains sand laminae.	44.5	63
Unit 3.	Sandstone, tan, calcareous, flaggy.	6.7	60
Unit 4.	Dolomite, tan, sandy; with interbedded sand laminae.	6.9	20
Unit 5.	Quartzite, gray-green, fine-grained, well-cemented.	9.7	99
Total thickness Worm Creek quartzite		70.8	

The Worm Creek quartzite conformably overlies the Nounan formation.

Green Canyon section

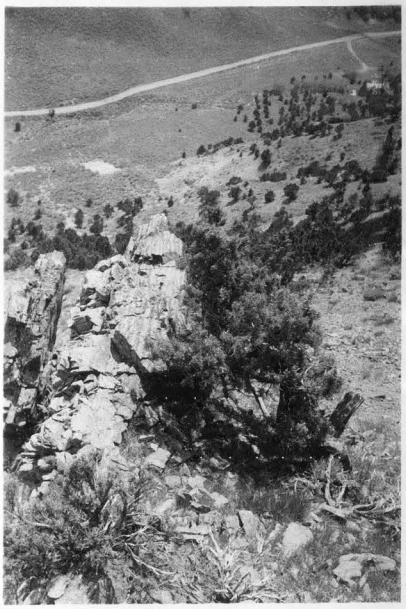
The Green Canyon section is located approximately 4 miles northeast of Logan, Utah, 1 mile east in Green Canyon. The outcrop measured is near the crest of the ridge due north of the old firing range on the north side of the canyon. The red and brown talus slopes near this area are from the Worm Creek and can be easily traced directly to the quartzite outcrop. The area is easily accessible by automobile, and the outcrop is a short climb from the road.

The section in this area is on the western limb of the Logan Peak synocline. The beds dip from nearly vertical to 75° eastward and strike just east of north. As a consequence of the severe folding the area is badly deformed and broken. Adequate measureable outcrops were found which displayed the basal quartzite of the member as prominent vertical ridges (Plate 2), but the upper calcareous unit was poorly exposed. As was the case in the Blacksmith Fork Canyon section, a major part of the Worm Creek is the upper unit consisting of silty and sandy limestone. This was the first area studied that showed a distinct calcareous unit dividing the basal quartzite into two separate units, the upper unit being the thinner. The divider in this case is a limestone unit, while other areas had only dolomitic quartzite or sandstone as a divider. The Worm Creek in Green Canyon shows no distinctive features or fossils. Little crossbedding was found in either the basal quartzite or upper limestone.

TABLE 4. GREEN CANYON SECTION

Location - Sec. 13, T 10 N, R 2 W, Cache County, Utah

Description - Section of Upper Cambrian strata measured on the north



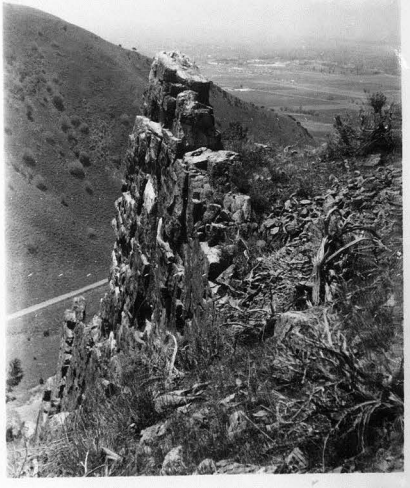


PLATE 2. Nearly vertical Worm Creek quartzite in Green Canyon.

side of Green Canyon, approximately 3 miles from Logan, Utah. The section was measured near the crest of the hill north of the old shooting range. Measured and sampled by A.V. Haynie, Jr. on 6 May 1956. Insoluble residue analysis completed July 1956.

Middle member, St. Charles formation conformably overlies the Worm Creek quartzite.

Worm Creek quartzite:		feet	% Clastic
Unit 1.	Dolomite, light gray, coarsly crystalline, sandy.	29.0	24
Unit 2.	Dolomite, light gray, sandy; contains sand laminae, poorly exposed	80.0	38
Unit 3.	Quartzite, gray, fine-grained, well-cemented.	1.0	86
Unit 4.	Limestone, light gray, sandy.	4.0	49
Unit 5.	Quartzite, gray, fine-grained, well-cemented.	6.0	99
Total thickness Worm Creek quartzite.		120.0	

The Worm Creek quartzite conformably overlies the Nounan formation.

Clarkston section

The Clarkston section is located 5 miles west of Clarkston, Utah, on the southwest end of the Basin and Range Malad Range, and about 1500 feet down from the crest of Gunsight Peak (Clarkston mountain). There are no adequate roads close to the area measured. The road west from Clarkston is closest to the area, but a 3 hour climb was necessary to reach an adequate outcrop. The Worm Creek exposures near the road on the southern limit of the range are easily accessible, but the area is badly broken by many small normal faults, making measurement impossible. The quartzite in the area measured was exposed as a minor tan, blocky cliff overlain by slope-forming limestone. The basal quartzite exhibited some cross-bedding, although it was not prominent. A dolomitic

horizon separates the basal quartzite into two units, but the separation in this area was not as distinct as in the Green Canyon or Call's Fort sections; the area was more like the St. Charles Canyon section than any other. The Worm Creek reached a thickness of 140 feet, with the upper 80 feet consisting of silty and sandy limestone and dolomite.

TABLE 5. CLARKSTON SECTION

Location - Sec. 17, T 12 N, R 2 E, Box Elder County, Utah.

Description - Section of Upper Cambrian strata measured on the western side of Gunsight Peak (Clarkston mountain) approximately 1500 feet down from the crest of the peak, and 3 miles North of Plymouth, Utah. The section was measured and sampled by A. V. Haynie, Jr. and Darrell Eliason on 10 June 1956. Insoluble residue analysis completed in July 1956.

Middle member, St. Charles formation conformably overlies Worm Creek quartzite.

Worm Creek quartzite:		feet	% Clastic
Unit 1.	Dolomite, gray sandy; with interbedded silt and sand.	52.0	43
Unit 2.	Limestone, gray; with interbedded sand and silt.	29.0	27
Unit 3.	Quartzite, white to gray, fine-grained, well-cemented.	8.0	93
Unit 4.	Quartzite, light gray, dolomitic; with sandstone lenses.	3.0	89
Unit 5.	Limestone, gray, crystalline; sandy; with interbedded silt.	12.0	38
Unit 6.	Dolomite, light gray, sandy; with interbedded sand.	25.0	43
Unit 7.	Quartzite, light gray to tan, dolomitic, sandy.	11.0	90
Total thickness Worm Creek quartzite		140.0	

The Worm Creek quartzite conformably overlies the Nounan formation.

Dry Canyon section

The Dry Canyon section is located on the southern tributary of Dry

Creek, 8 miles west of Weston, Idaho. The area is accessible by automobile, since the area is used as a sheep and cattle range and is kept open to farm traffic. The section measured is located on a small hill to the south of Dry Creek, and just east of a cattle watering and leading point. The Worm Creek in this area occupies the upper 1/3 of the hill. The section is bounded on the north by a normal fault along which Dry Creek flows. The beds in the area strike 12° northeast and dip 30° eastward. The section is poorly exposed, but adequate exposures were found for measurement and sampling. The Worm Creek in this area weathers to a smooth, gentle slope. Where outcrops are present, the quartzite is displayed as minor white, blocky ridges and cliffs (Plate 3). As in other sections, the basal quartzite is separated into an upper and lower unit by a calcareous unit. The section is similar to the lower part of the St. Charles section; however, the upper limestone unit is missing in this section and no comparable unit is present. The basal quartzite is overlain directly by the crinkly limestone of the middle St. Charles (Plate 3).

TABLE 6. DRY CANYON SECTION

Location - Sec. 4, T 16 S, R 37 E, Oneida County, Idaho.

Description - Section of Upper Cambrian strata measured on the eastern side of a small hill south of the southern tributary of Dry Creek, near cattle loading and watering point. The top of section is located at crest of the hill. The section was measured and sampled by A. V. Haynie, Jr. on 27 June 1956. Insoluble residue analysis completed July 1956.

Middle member, St. Charles formation conformably overlies the Worm Creek quartzite.

Worm Creek quartzite:		feet	% Clastic
Unit 1.	Quartzite, tan to gray, calcareous; with interbedded, crossbedded sand.	16.0	55
Unit 2.	Quartzite, tan, calcareous, fine-grained contains minor limonite.	5.0	86

A. Worm Creek quartzite exposed as minor blocky cliff in Dry Canyon

B. Upper contact of the Worm Creek quartzite with overlying crinkly limestone in Dry Canyon

PLATE 3. Worm Creek quartzite in Dry Canyon

Unit 3.	Sandstone, tan, dolomitic; with cross-bedded sand laminae.	2.0	60
Unit 4.	Quartzite, tan, fine-grained, well-cemented; banded.	33.0	84
Unit 5.	Quartzite, white, fine-grained, well-cemented; minor crossbedding.	7.0	98
Total thickness Worm Creek quartzite		63.0	

The Worm Creek quartzite conformably overlies the Nounan formation.

Promontory section

The Promontory section is located 26 miles south of the Utah highway 83- Promontory Point road junction on the Promontory Point road, and about 5 miles north of the Morrison-Knudsen construction camp and Union Pacific railroad Lucin cutoff. The section itself is contained in the only Cambrian rocks present in the Promontory range, and is exposed in the crest of the range, which falls in the Basin and Range province. A side road cutting to the west just past the single cattle guard passed leads to a point just west of the section.

The beds in this area strike 40° northwest, and dip 40° northeast. This section is much thicker than was expected in this area, and was quite similar to the Bear Lake sections. This section, like the Call's Fort section, contained a major thickness of green shale at the top, which graded into the overlying crinkly limestone.

TABLE 7. PROMONTORY SECTION

Location - Sec. 21, T 7 N, R 5 W, Weber County, Utah.

Description - Section of Upper Cambrian strata measured on the crest of the Promontory range 5 miles north of the Lucin cut-off, and 26 miles south of Utah 83-Promontory Point road junction. Section measured by A. V. Haynie, Jr., J. Stewart Williams, and Richard Olsen on 11 July 1956. Insoluble residue analysis completed July 1956.

Middle member, St. Charles formation conformably overlies Worm Creek quartzite.

Worm Creek quartzite:		feet	% Clastic
Unit 1.	Shale, tan to green, fissle.	15.0	98
Unit 2.	Sandstone, tan, calcareous, blocky.	5.0	69
Unit 3.	Limestone, gray, sandy; with sand laminae.	42.0	16
Unit 4.	Quartzite, white, fine-grained, well cemented.	1.0	99
Unit 5.	Dolomite, light gray, crystalline, sandy; with sand laminae.	2.5	20
Unit 6.	Quartzite, white to tan, fine-grained, crossbedded.	1.5	87
Unit 7.	Quartzite, white, fine-grained, well-cemented; with prominent white bands.	2.0	95
Total thickness Worm Creek quartzite		67.0	

The Worm Creek quartzite conformably overlies the Nounan formation.

Other areas

Besides these seven measured sections many other localities were checked for the presence of the Worm Creek quartzite. Already mentioned was the Laketown canyon area, which presented a considerable thickness of the Worm Creek. In addition, Worm Creek exposures were found near Rendezvous Peak, Utah; and at a point just southeast of a minor reservoir 2 miles northwest of Standing Rock Pass, Idaho, which is 7 miles northwest of Weston, Idaho. Probable exposures were found in Willow Flat, 14 miles east of Preston, Idaho, and in Mink Creek Canyon, 4 miles northeast of Mink Creek, Idaho. Upper Cambrian sections north of Lava Hot Springs, Idaho, northwest of Malad City, Idaho, and along the Emigration Pass, Idaho, road were checked for possible Worm Creek exposures, but none were definitely identified.

Robert Bright (personal communication) reported a thickness of Worm Creek estimated at over 200 feet in the Emigration Canyon, Idaho area;

he had reports concerning, but had not seen, a section of Worm Creek estimated to be nearly 600 feet thick near Soda Springs, Idaho. Because of weather and time restrictions, neither of these sections could be checked. Bright mentioned that both of these sections contained appreciable felspar, with the feldspar content increasing northward to the Soda Springs section, which consisted of up to 90% feldspar in certain horizons. The quartzite studied to the south contained no feldspar; it consisted of quartz, with minor mica, and some samples contained limonite.

LABORATORY ANALYSIS

General Statement

A laboratory study of Worm Creek quartzite samples was made in the hope that additional information concerning the mode and conditions of deposition of the Worm Creek would be obtained. First phase of the study was an insoluble residue analysis and residue examination, which was followed by thin sectioning of selected quartzite samples. These sections were used mainly for structure examination of the quartzite.

Insoluble residue analysis

The basic procedure for the insoluble residue analysis was taken from Ireland. The procedure was refined to suit the needs of the problem by the writer, with assistance from J. Stewart Williams and D. R. Olsen of the Utah State Agricultural College.

The preparation of the samples for testing was relatively simple, but vitally important to the experiment. Small chips of the sample to be tested were taken from each sample. Clean, freshly broken chips with minimum surface weathering were placed in a small crusher and pulverizer and reduced to small, easily soluble particles. Initially it was found

that this simple crushing procedure could be a long and tiresome task; however, this was remedied by the construction of a simple, but effective, crushing device. This device consisted of a 4-inch long piece of 1-inch steel tubing fitted with a welded steel plug in one end. This cylinder was then fitted with a ram made from a steel bolt of the proper size. A medium-sized hammer completed the crushing apparatus, which proved entirely adequate for use in this study.

Initially, 100 cc. beakers were cleaned and marked for each of the nearly 100 samples to be tested. Then each beaker was individually weighed to the nearest milligram on a balance. The prepared sample was then poured into the beaker and the combined weight of the beaker and sample was determined. From this the sample weight was found. After the weighing process the sample was covered with dilute hydrocloric acid. It was found that the acid and the pulverized samples sometimes reacted almost explosively. This resulted in a loss of some of the sample, and consequently, an inaccurate test. This was corrected by barely covering the sample with distilled water prior to the addition of the acid. This was to slow the reaction. After the acidizing of the sample, the beaker was placed in a marked drawer for at least 24 hours, so that the reaction might be as complete as possible. Additional acid was added during the course of the tests to insure that the reaction had gone to completion. After the reaction was completed, the samples were decanted and filtered through filter paper which had been previously marked and weighed to the same accuracy as the beakers, and washed with distilled water. The paper and sample were then heat-dried, cured under room conditions for approximately 15 minutes, and reweighed. From the two weighings the weight of the residue was computed. It might be noted that the curing of the paper and sample under room conditions is necessary to insure accuracy in determining the weight of the samples,

especially those which were the residue of predominately carbonate samples, since these gave little residue. Differences of 20 to 50 milligrams were found in weighings of the same uncured and cured paper and sample. This difference could introduce considerable error, since some of the residues weighed less than 400 milligrams.

Results of the insoluble residue analysis are presented in the tabular descriptions of the sections as a per cent clastic content. These results showed that the silty limestones and dolomites which are under the Worm Creek in all areas to be generally less than 20% clastic material and usually ranged from 9% to 15% clastic material, whereas units included as part of the Worm Creek quartzite contained usually greater than 50% clastic material, and generally in the neighborhood of 85-95% clastic material. The upper limestone unit of the Worm Creek contained about 20-40% clastic material, which was appreciably higher than the underlying Nounan formation. It was found through this insoluble residue analysis that field determinations are sometimes inaccurate and can be misleading as to carbonate-clastic content. Some of the samples classified as calcareous clastics in the field were found to contain less than the accepted 50% clastic material necessary for that classification. The breaks from predominately clastic to predominately carbonate units was found to be quite sharp by the insoluble residue analysis.

Thin section analysis

Thin sections were cut from selected samples of the quartzite. Three sections were cut from each sample: one parallel to the bedding, two perpendicular to the bedding and at right angles to each other. This method, it was hoped, would give complete exposure to any structure within the quartzite sample; however, no pronounced features of bedding,

imbrication, or grading were seen. The sections did show good sorting of the sub angular to rounded, predominately quartz grains. Some limonite is contained by the quartzite; no feldspar was found.

STRATIGRAPHIC ANALYSIS

General features

Lithology. The Worm Creek quartzite consists generally of light gray, tan or white basal quartzite, with a major calcareous unit located in the upper half of the section. This calcareous unit is either a calcareous siltstone or a sandy limestone. Cross-bedding is prominent in both the clastic and carbonate units of the member in some of the sections studied. The quartzite weathers characteristically tan to red, although some beds of the quartzite are resistant to weathering and exhibit a clean, white surface (Plate 4). The quartzite, sandstone, and limestone which comprise the Worm Creek quartzite are bounded on the bottom by a silty and sandy limestone and on the top by a crinkly limestone. The sand and silt in the underlying Nounan formation form prominent layers in the limestone which range from about 2 mm. to 2 cm. in thickness. These layers sharpen the cross-bedding displayed by the calcareous units (Plate 1). Float from these limestone units show well-defined mud cracks, ripple marks, and other features diagnostic of shallow, near shore deposition.

In some areas the quartzite is capped by a green shale unit which is included as part of the Worm Creek quartzite. This shale contains no fossils. The absence in most areas, rather than the presence in restricted areas, of this shale unit may present evidence as to the environment of deposition of the Worm Creek quartzite. It may be noted that the shale graded into the overlying crinkly limestone in the Promontory section, and the laminations of the limestone were of the same shaly material as

A. Basal unit of the Worm Creek at Promontory showing resistant orthoquartzite bands.

B. Prominent crossbedding displayed in silty limestone of the Worm Creek

PLATE 4. Sedimentary structures in the Worm Creek quartzite.

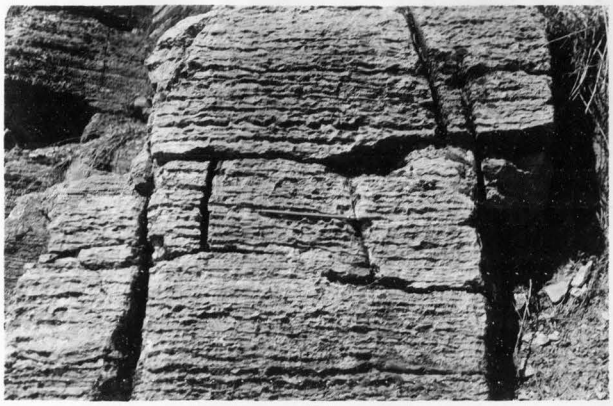
the underlying shale, both in color and texture. This is also the case in the Call's Fort section.

The Worm Creek quartzite overlies the Nounan formation and is succeeded by the fossiliferous middle dolomite and limestone member of the St. Charles formation. Directly over the Worm Creek this is a limestone containing sand-silt layers which are more resistant to weathering than the limestone. These resistant layers are approximately 5 mm. in thickness and are spaced from 1 to 2 cm. apart. Some of these layers appear to intertwine. These resistant laminations give the limestone a crinkly appearance (Plate 5).

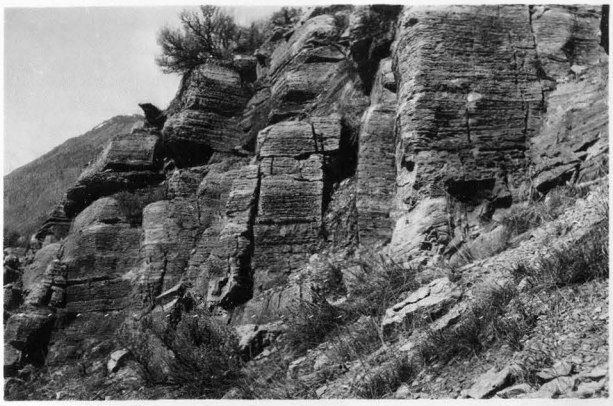
Since the Worm Creek quartzite is a predominantly clastic unit in a thick carbonate succession, the Worm Creek is defined as the quartzite, sandstone, and shale unit between the crinkly limestone on the top, and the base at the bottom of the quartzite, approximately 150 feet above the more prominent cliffs of the Nounan formation. The base of the member is well defined where exposures can be found, since there is a distinct change in lithology; however, often the base is covered. The top contact is sharp and can usually be seen.

The Worm Creek quartzite generally forms a series of prominent, blocky cliffs, with a smooth, covered interval at the top representing the upper calcareous unit. The overlying ~~Nounan~~ St Charles formation weathers to a smooth, gentle surface interrupted by minor, rounded cliffs (Plate 6). The weathering qualities of the upper calcareous unit of the Worm Creek often gives rise to partially or completely covered section, and make recognition and measurement of some sections extremely difficult.

Thickness. The Worm Creek quartzite varies from 63 feet thick at the Dry Canyon section to 140 feet thick at the Clarkston section. The Worm Creek thins to east and northeast of the area studied; it thickens



A. Close-up view of crinkly limestone.



B. Blocky cliffs of crinkly limestone in Blacksmith Fork Canyon.

PLATE 5. Crinkly limestone cliffs above the Worm Creek quartzite.

A. Blocky cliffs of Worm Creek at St. Charles Canyon

B. Worm Creek quartzite as a series of blocky cliffs flanked by smooth slopes in St. Charles Canyon.

PLATE 6. Blocky cliffs of Worm Creek quartzite.

generally toward the central part of the area studied (Figures 5, 6, 7). The basal quartzite unit varies from 63 feet, the total thickness, at the Dry Canyon section, to 3 feet thick at the Blacksmith Fork section.

Areal extent. The Worm Creek quartzite is present as a clastic and carbonate unit in the Bear River Range of Utah and Idaho. Robert Bright (Personal communication) found a considerable thickness of predominately clastic rock northeast of Preston, Idaho, which he suggested was Worm Creek quartzite. He also stated that a thick section of predominately clastic rock presumed to be Worm Creek quartzite had been found near Soda Springs, Idaho. The Worm Creek is present as a quartzite and sandstone unit in the Northern Malad Range, east of Malad City, Idaho. The member changes to a clastic and carbonate unit to the south, and is present as a quartzite, limestone, and shale unit in the Promontory range, east of Ogden, Utah. The Worm Creek quartzite was not found south or west of the Promontory Range, nor was it found east of Laketown, Utah.

Lithologic units

The Worm Creek quartzite generally consists of two major units; a basal quartzite unit and an upper carbonate unit. The basal quartzite is usually further divided by a calcareous sandstone unit or a carbonate unit. In restricted areas the upper carbonate unit is capped by a green shale. In the Dry Canyon area to the northwest of the area studied the upper carbonate unit is missing; however, the rest of the area studied follows the general pattern of a basal quartzite, a calcareous or carbonate unit, another quartzite or sandstone, and finally a major carbonate unit which is capped by a green shale in the southwestern areas.

Age

The Worm Creek quartzite is of lower Franconian age, and is in the Elvinia faunal zone, as defined by Howell (1944). The quartzite itself

is not fossiliferous. The only known fossils found were U-shaped markings which resembled those of Polychaeta, a class of marine worms common along sea coasts (Plate 7). This order of worms ranges from Precambrian to Recent, and, thus, was of no use in dating the member. These markings were found only in certain horizons in the basal quartzite of the St. Charles Canyon section.

Maxey (1941) found trilobite remains representing Elvinia, Iddingsia, and Irvingella in the limestone unit above the Worm Creek; he identified a Dunderbergia zone below the Worm Creek. Since no disconformable relationship has been found in or near the quartzite, it is assumed that the overlying and underlying units can be used to define the age of the Worm Creek quartzite, which is lower Upper Cambrian, or Franconian.

PALEOGEOGRAPHIC SYNTHESIS

General Statement

Areal extent. The present known extent of the Worm Creek quartzite represents a major portion of the quartzite as it was deposited. Beach or littoral sands to the east of the area indicate that deposition probably did not extend further in that direction. The northern arkosic sandstones reported near Soda Springs, Idaho, probably represent terrestrial deposits near the source area of the Worm Creek. The Worm Creek loses its identity to the southwest beyond the Blacksmith Fork Canyon area. The western limits cannot be defined, although the Worm Creek was probably not deposited much further northwest than that exposed at Dry Canyon.

The present thickness is consistant with the deposited thickness except for the minor effect of compaction. No evidence of unconformaties was found.

Lithologic associations. The Worm Creek quartzite is a relatively

PLATE 7. Fossil worm burrows of Polychatea as seen in St. Charles Canyon.

thin, blanket-type quartzite and sandstone which wedges out gradually to the southwest. It is characteristic of basal sandstones described by Dapples (1947) as platform sandstones which "accumulate under conditions of tectonic stability and steady, uniform currents." The area of deposition of the Worm Creek was, at its time of deposition, part of the shelf area of the Cordilleran geosyncline and considered part of the craton, or stable interior of the continent, during Paleozoic time; and since the Cordilleran area represents a major inland sea, currents would have been comparatively steady and uniform. The green shale is suggestive of a stable area at the time of its deposition (Krumbein and Sloss, 1955).

Lithofacies

The Worm Creek quartzite is predominately a clastic rock to the north, east and west of the area studied, and changes to a predominately carbonate rock to the south and toward the central part of the area. Vertically the Worm Creek changes upward from sandstone and quartzite to a calcareous sandstone or silty and sandy limestone.

In the vicinity of Dry Canyon the Worm Creek is a clastic rock for its entire thickness, while in the Blacksmith Fork Canyon area the Worm Creek is nearly all limestone, with a minor quartzite and sandstone unit at the base. The quartzite in the southwest of the area at the Promontory section is predominately clastic, although the member here is definitely more calcareous than at Dry Canyon to the north. A conspicious thickness of green shale is present at the top of the Worm Creek in the area of the two southwest sections, Promontory and Call's Fort.

Sedimentary tectonics

Since the Worm Creek quartzite grades upward from a sandstone to a limestone, it is the basal sandstone of a transgressive sea moving over the shelf area of the Cordilleran geosyncline. At the time of the

deposition of the basal quartzite of the Worm Creek the subsidence of the geosyncline and transgression of the sea was slow (Figure 4a). The sand supplied by a granitic land mass to the north was well washed, the grains became somewhat worn and well sorted. Unstable minerals were removed. This condition continued through the deposition of the basal quartzite and calcareous or carbonate unit overlying it. Then the deposition sped up slightly, resulting in the second quartzite being deposited (Figure 4b). The sand grains of this second quartzite unit are similar to the basal quartzite, being sub-angular to round and well-sorted; the unstable minerals have been removed. As the sea continued to transgress, the deposition again slowed, resulting in the silty and sandy limestone deposition. The uniform slope of the western side of the Cordilleran geosyncline and the uniform transgression of the sea resulted in a nearly normal sequence of sedimentation in the western areas. To the east the abrupt change from the basin of the geosyncline to the shelf area modified the sedimentation sequence. As the sea transgressed over the shelf area it pushed the source area for the sand far to the north and east. This resulted in a sedimentation sequence which did not include a shale unit, but moved directly from a sandstone unit to a limestone unit, (Figure 4c).

Source area

The source area of the Worm Creek quartzite was a land mass or island arc located in the vicinity of central Idaho. The high feldspar content reported in the sections north of the area studied indicates a source in that vicinity. Apparently the Worm Creek, which approaches an arkose in composition near Soda Springs, Idaho, is terrestrial in origin and is near the source area. As the material was carried south it was well worked over, the unstable minerals were removed, and the detrital sand grains were well sorted as they were deposited.

CONCLUSIONS

The Worm Creek quartzite represents the basal sandstone of a transgressive Franconian sea, with the source area just north of the Utah-Idaho border. The member is a first phase sandstone, with the source area a granitic land mass; the Worm Creek is a relatively thin, blanket-type quartzite and sandstone which wedges out to the southwest.

Near the source area the Worm Creek is a terrestrial arkosic sandstone; further to the south it is a platform sand, consisting of subangular to rounded quartz grains. The member is subdivided into two major units, the lower quartzite and the upper carbonate unit. The lower quartzite unit is further divided into a basal quartzite, and calcareous sandstone or carbonate unit, and an upper quartzite unit. In some areas a green shale overlies the upper carbonate unit and is included as part of the Worm Creek quartzite.

The Worm Creek quartzite is the only clastic unit in a thick succession of carbonate rocks, and is usually seen as minor, blocky cliffs of the lower quartzite, overlain by a smooth slope formed by the upper limestone unit.

The Worm Creek quartzite was deposited on the shelf area of the Cordilleran geosyncline, a stable area during the period of deposition, and was the result of a transgressive sea, slow subsidence of the geosyncline, and slow deposition.

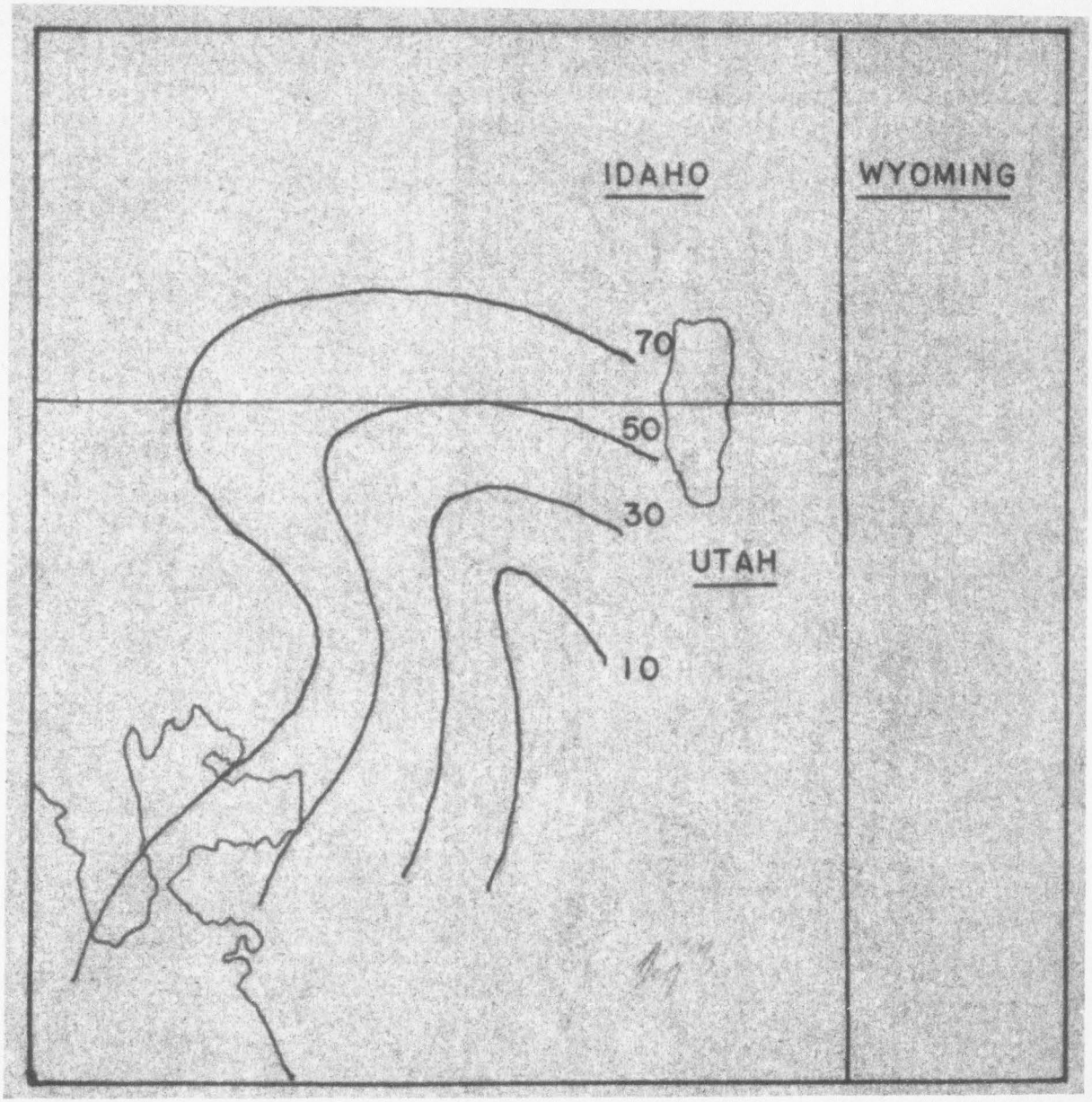


FIGURE 3. Isopach map of the clastic unit of the Worm Creek quartzite

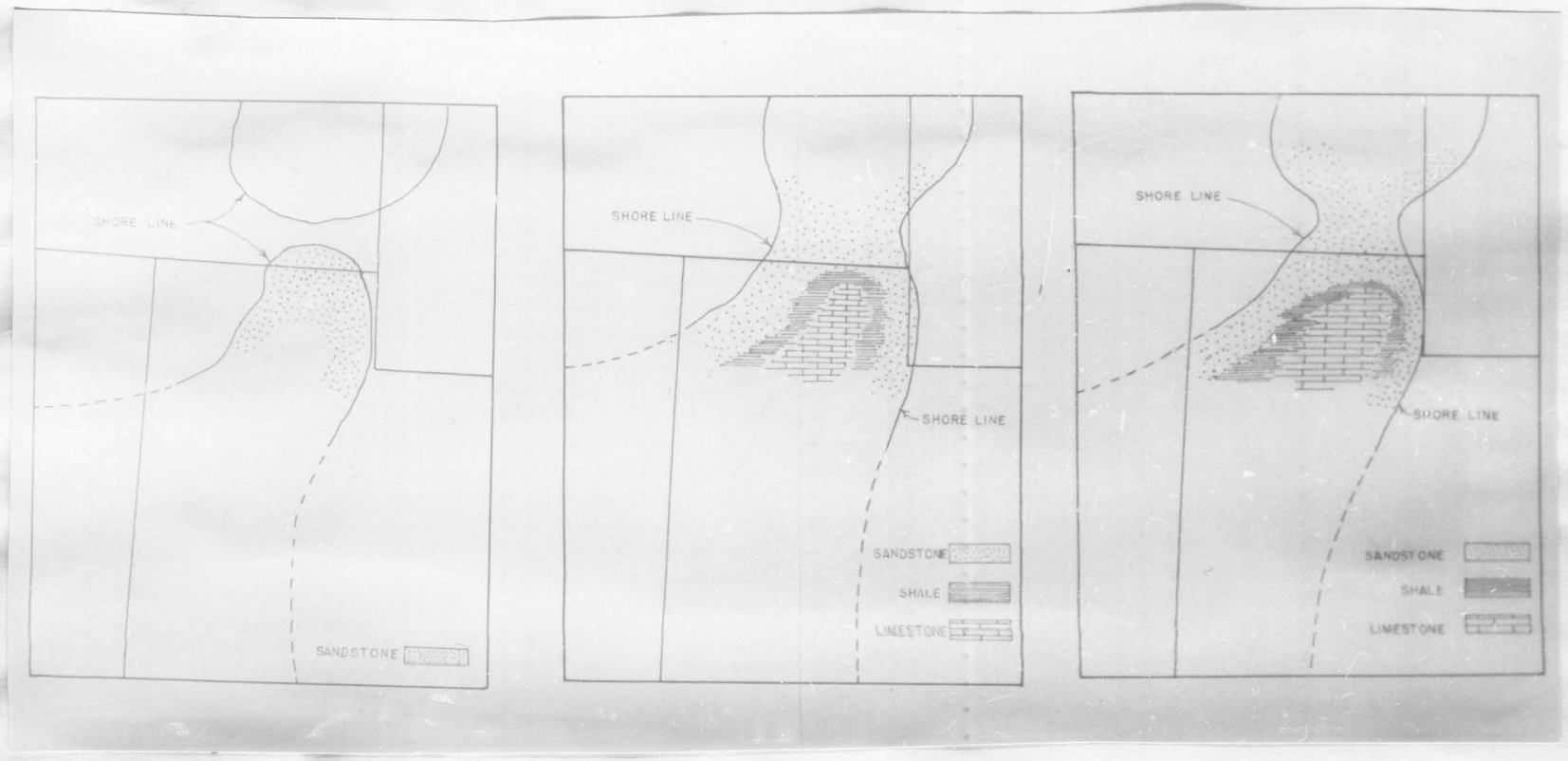


FIGURE 4. Map showing paleogeography and lithofacies of the Worm Creek quartzite

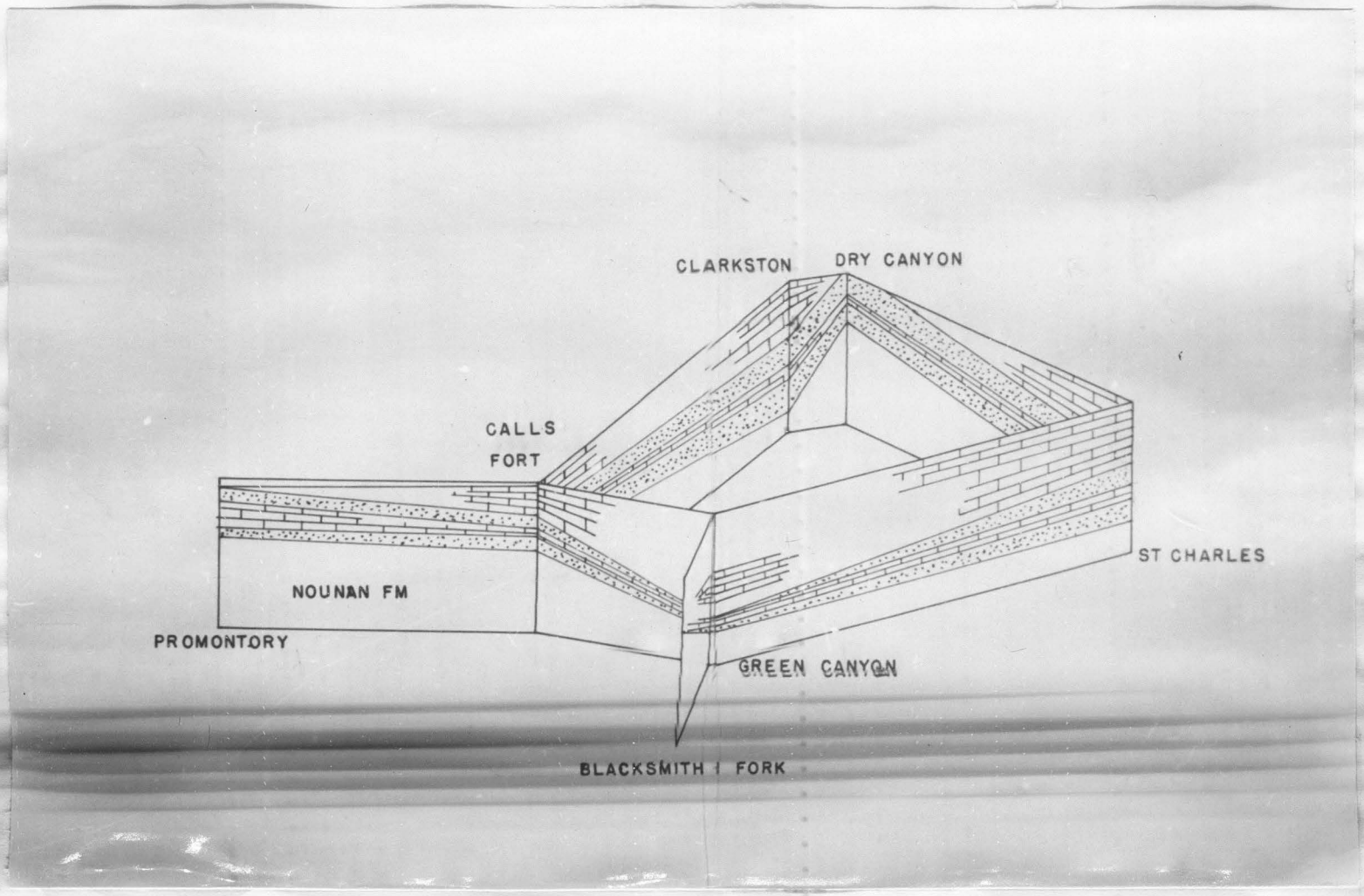


FIGURE 5. Isometric stratigraphic diagram of the Worm Creek quartzite

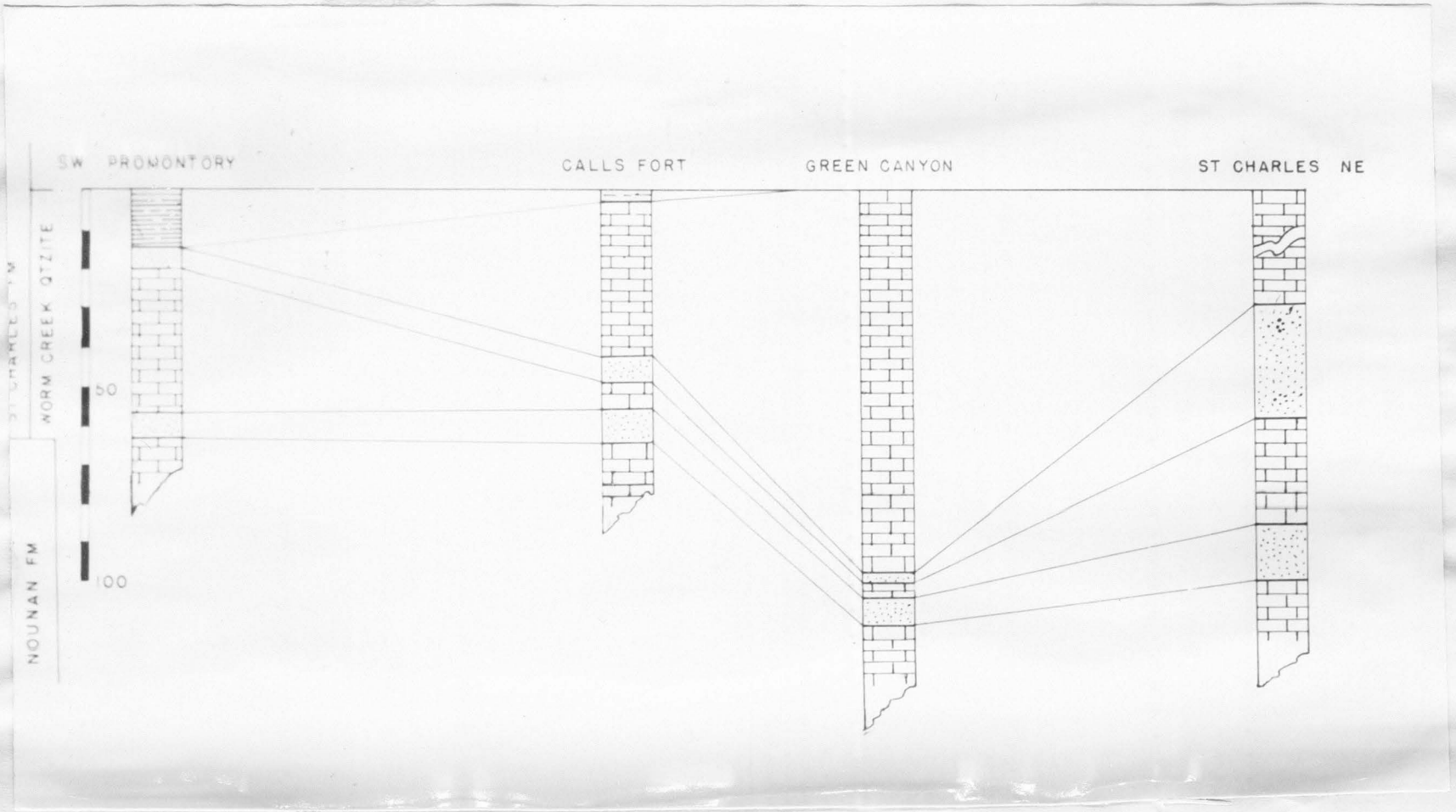


FIGURE 6. Generalized stratigraphic northeast cross section of the Worm Creek quartzite

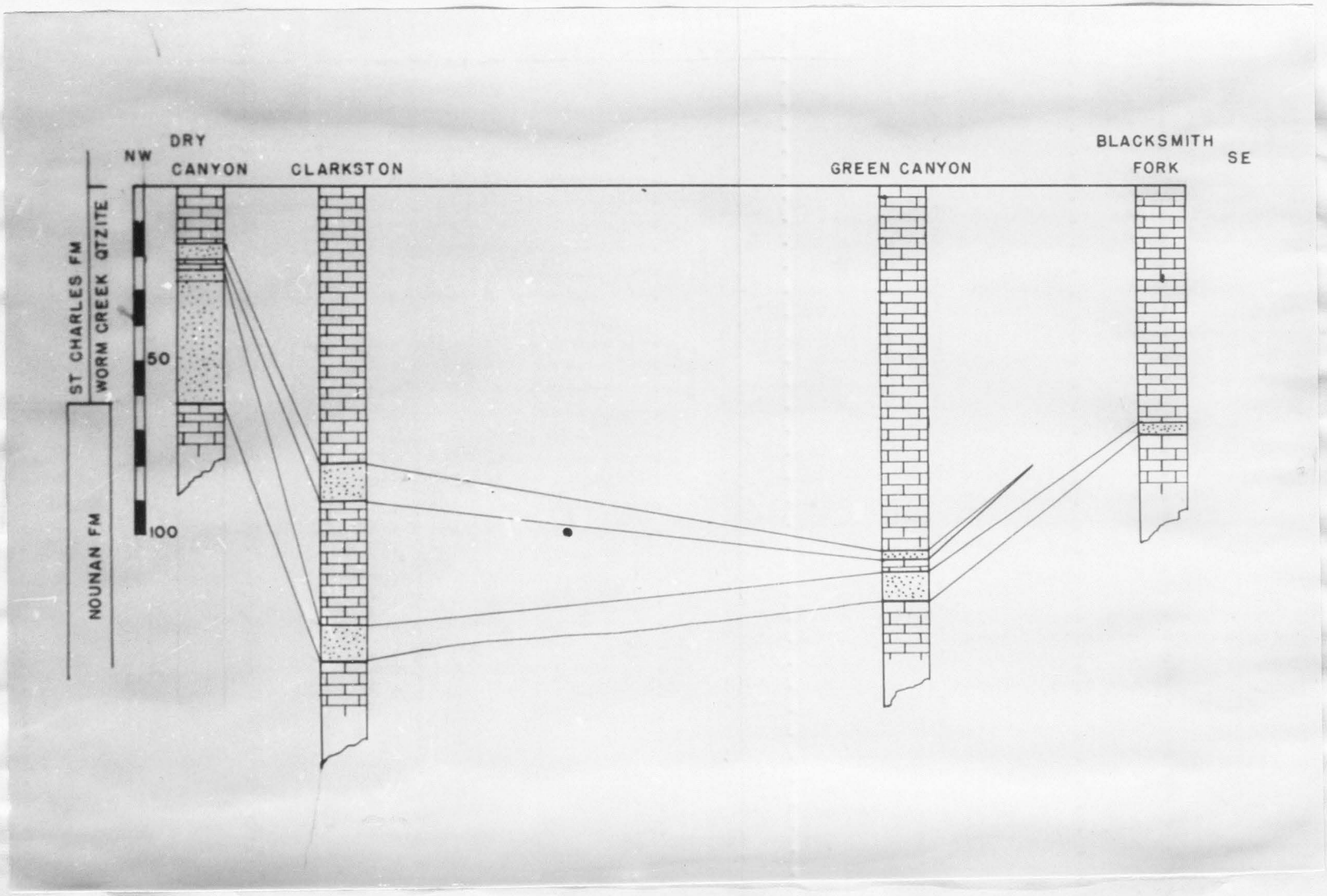


FIGURE 7. Generalized stratigraphic southeast cross section of the Worm Creek quartzite

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